Oligopoly Games

Economists think about oligopoly as a game between two or a few players, and to study oligopoly markets they use game theory. **Game theory** is a set of tools for studying *strategic behavior*—behavior that takes into account the expected behavior of others and the recognition of mutual interdependence. Game theory was invented by John von Neumann in 1937 and extended by von Neumann and Oskar Morgenstern in 1944 (p. 367). Today, it is one of the major research fields in economics.

Game theory seeks to understand oligopoly as well as other forms of economic, political, social, and even biological rivalries by using a method of analysis specifically designed to understand games of all types, including the familiar games of everyday life (see Talking with Thomas Hubbard on pp. 368–370). To lay the foundation for studying oligopoly games, we first think about the features that all games share.

What Is a Game?

What is a game? At first thought, the question seems silly. After all, there are many different games. There are ball games and parlor games, games of chance and games of skill. But what is it about all these different activities that makes them games? What do all these games have in common? All games share four common features:

- Rules
- Strategies
- Payoffs
- Outcome

We're going to look at these features of games by playing at a game called "the prisoners' dilemma." The prisoners' dilemma game displays the essential features of many games, including oligopoly games, and it gives a good illustration of how game theory works and generates predictions.

The Prisoners' Dilemma

Art and Bob have been caught red-handed stealing a car. Facing airtight cases, they will receive a sentence of two years each for their crime. During his interviews with the two prisoners, the district attorney begins to suspect that he has stumbled on the two people who were responsible for a multimillion-dollar bank robbery some months earlier. But this is just a suspicion. He has no evidence on which he can convict them of the greater crime unless he can get them to confess. But how can he extract a confession? The answer is by making the prisoners play a game. The district attorney makes the prisoners play the following game.

Rules Each prisoner (player) is placed in a separate room and cannot communicate with the other prisoner. Each is told that he is suspected of having carried out the bank robbery and that

> If both of them confess to the larger crime, each will receive a sentence of 3 years for both crimes.
>
> If he alone confesses and his accomplice does not, he will receive only a 1-year sentence while his accomplice will receive a 10-year sentence.

Strategies In game theory, **strategies** are all the possible actions of each player. Art and Bob each have two possible actions:

1. Confess to the bank robbery.
2. Deny having committed the bank robbery.

Because there are two players, each with two strategies, there are four possible outcomes:

1. Both confess.
2. Both deny.
3. Art confesses and Bob denies.
4. Bob confesses and Art denies.

Payoffs Each prisoner can work out his *payoff* in each of these situations, and we can tabulate the four possible payoffs for each of the prisoners in what is called a payoff matrix for the game. A **payoff matrix** is a table that shows the payoffs for every possible action by each player for every possible action by each other player.

Table 15.1 shows a payoff matrix for Art and Bob. The squares show the payoffs for each prisoner—the red triangle in each square shows Art's and the blue triangle shows Bob's. If both prisoners confess (top left), each gets a prison term of 3 years. If Bob confesses but Art denies (top right), Art gets a 10-year sentence and Bob gets a 1-year sentence. If Art confesses and Bob denies (bottom left), Art gets a 1-year sentence and Bob gets a 10-year sentence. Finally, if both of them deny (bottom right), neither can be convicted of the bank robbery charge but both are sentenced for the car theft—a 2-year sentence.

TABLE 15.1 Prisoners' Dilemma Payoff Matrix

Bob's strategies \ Art's strategies	Confess	Deny
Confess	3 years / 3 years	10 years / 1 year
Deny	1 year / 10 years	2 years / 2 years

Each square shows the payoffs for the two players, Art and Bob, for each possible pair of actions. In each square, the red triangle shows Art's payoff and the blue triangle shows Bob's. For example, if both confess, the payoffs are in the top left square. The equilibrium of the game is for both players to confess and each gets a 3-year sentence.

Outcome The choices of both players determine the outcome of the game. To predict that outcome, we use an equilibrium idea proposed by John Nash of Princeton University (who received the Nobel Prize for Economic Science in 1994 and was the subject of the 2001 movie *A Beautiful Mind*). In **Nash equilibrium**, player *A* takes the best possible action given the action of player *B* and player *B* takes the best possible action given the action of player *A*.

In the case of the prisoners' dilemma, the Nash equilibrium occurs when Art makes his best choice given Bob's choice and when Bob makes his best choice given Art's choice.

To find the Nash equilibrium, we compare all the possible outcomes associated with each choice and eliminate those that are dominated—that are not as good as some other choice. Let's find the Nash equilibrium for the prisoners' dilemma game.

Finding the Nash Equilibrium Look at the situation from Art's point of view. If Bob confesses (top row), Art's best action is to confess because in that case, he is sentenced to 3 years rather than 10 years. If Bob denies (bottom row), Art's best action is still to confess because in that case he receives 1 year rather than 2 years. So Art's best action is to confess.

Now look at the situation from Bob's point of view. If Art confesses (left column), Bob's best action is to confess because in that case, he is sentenced to 3 years rather than 10 years. If Art denies (right column), Bob's best action is still to confess because in that case, he receives 1 year rather than 2 years. So Bob's best action is to confess.

Because each player's best action is to confess, each does confess, each goes to jail for 3 years, and the district attorney has solved the bank robbery. This is the Nash equilibrium of the game.

The Nash equilibrium for the prisoners' dilemma is called a **dominant-strategy equilibrium**, which is an equilibrium in which the best strategy of each player is to cheat (confess) *regardless of the strategy of the other player*.

The Dilemma The dilemma arises as each prisoner contemplates the consequences of his decision and puts himself in the place of his accomplice. Each knows that it would be best if both denied. But each also knows that if he denies it is in the best interest of the other to confess. So each considers whether to deny and rely on his accomplice to deny or to confess hoping that his accomplice denies but expecting him to confess. The dilemma leads to the equilibrium of the game.

A Bad Outcome For the prisoners, the equilibrium of the game, with each confessing, is not the best outcome. If neither of them confesses, each gets only 2 years for the lesser crime. Isn't there some way in which this better outcome can be achieved? It seems that there is not, because the players cannot communicate with each other. Each player can put himself in the other player's place, and so each player can figure out that there is a best strategy for each of them. The prisoners are indeed in a dilemma. Each knows that he can serve 2 years *only* if he can trust the other to deny. But each prisoner also knows that it is *not* in the best interest of the other to deny. So each prisoner knows that he must confess, thereby delivering a bad outcome for both.

The firms in an oligopoly are in a similar situation to Art and Bob in the prisoners' dilemma game. Let's see how we can use this game to understand oligopoly.

An Oligopoly Price-Fixing Game

We can use game theory and a game like the prisoners' dilemma to understand price fixing, price wars, and other aspects of the behavior of firms in oligopoly. We'll begin with a price-fixing game.

To understand price fixing, we're going to study the special case of duopoly—an oligopoly with two firms. Duopoly is easier to study than oligopoly with three or more firms, and it captures the essence of all oligopoly situations. Somehow, the two firms must share the market. And how they share it depends on the actions of each. We're going to describe the costs of the two firms and the market demand for the item they produce. We're then going to see how game theory helps us to predict the prices charged and the quantities produced by the two firms in a duopoly.

Cost and Demand Conditions Two firms, Trick and Gear, produce switchgears. They have identical costs. Figure 15.2(a) shows their average total cost curve (*ATC*) and marginal cost curve (*MC*). Figure 15.2(b) shows the market demand curve for switchgears (*D*). The two firms produce identical switchgears, so one firm's switchgear is a perfect substitute for the other's, and the market price of each firm's product is identical. The quantity demanded depends on that price—the higher the price, the smaller is the quantity demanded.

This industry is a natural duopoly. Two firms can produce this good at a lower cost than either one firm or three firms can. For each firm, average total cost is at its minimum when production is 3,000 units a week. When price equals minimum average total cost, the total quantity demanded is 6,000 units a week, and two firms can just produce that quantity.

Collusion We'll suppose that Trick and Gear enter into a collusive agreement. A **collusive agreement** is an agreement between two (or more) producers to form a cartel to restrict output, raise the price, and increase profits. Such an agreement is illegal in the United States and is undertaken in secret. The strategies that firms in a cartel can pursue are to

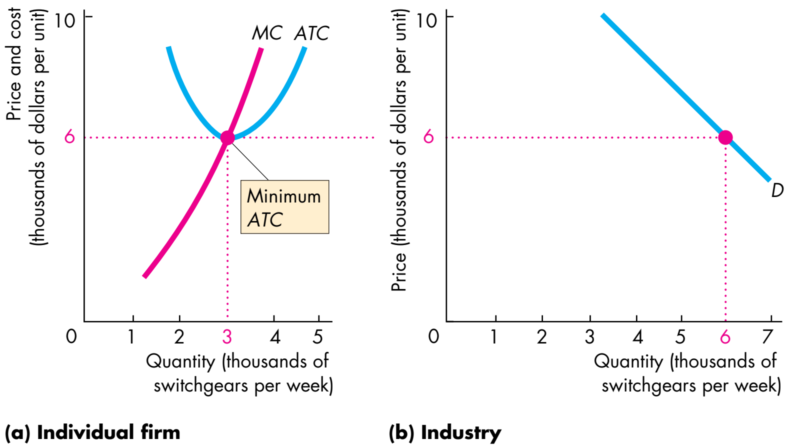
- Comply
- Cheat

A firm that complies carries out the agreement. A firm that cheats breaks the agreement to its own benefit and to the cost of the other firm.

Because each firm has two strategies, there are four possible combinations of actions for the firms:

1. Both firms comply.
2. Both firms cheat.
3. Trick complies and Gear cheats.
4. Gear complies and Trick cheats.

FIGURE 15.2 Costs and Demand



The average total cost curve for each firm is *ATC*, and the marginal cost curve is *MC* (part a). Minimum average total cost is $6,000 a unit, and it occurs at a production of 3,000 units a week.

Part (b) shows the market demand curve. At a price of $6,000, the quantity demanded is 6,000 units per week. The two firms can produce this output at the lowest possible average cost. If the market had one firm, it would be profitable for another to enter. If the market had three firms, one would exit. There is room for only two firms in this industry. It is a natural duopoly.

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Colluding to Maximize Profits Let's work out the payoffs to the two firms if they collude to make the maximum profit for the cartel by acting like a monopoly. The calculations that the two firms perform are the same calculations that a monopoly performs. (You can refresh your memory of these calculations by looking at Chapter 13, pp. 304–305.) The only thing that the firms in duopoly must do beyond what a monopoly does is to agree on how much of the total output each of them will produce.

Figure 15.3 shows the price and quantity that maximize industry profit for the duopoly. Part (a) shows the situation for each firm, and part (b) shows the situation for the industry as a whole. The curve labeled *MR* is the industry marginal revenue curve. This marginal revenue curve is like that of a single-price monopoly (Chapter 13, p. 302).The curve labeled MC_I is the industry marginal cost curve if each firm produces the same quantity of output. This curve is constructed by adding together the outputs of the two firms at each level of marginal cost. Because the two firms are the same size, at each level of marginal cost, the industry output is twice the output of one firm. The curve MC_I in part (b) is twice as far to the right as the curve *MC* in part (a).

To maximize industry profit, the firms in the duopoly agree to restrict output to the rate that makes the industry marginal cost and marginal revenue equal. That output rate, as shown in part (b), is 4,000 units a week. The demand curve shows that the highest price for which the 4,000 switchgears can be sold is $9,000 each. Trick and Gear agree to charge this price.

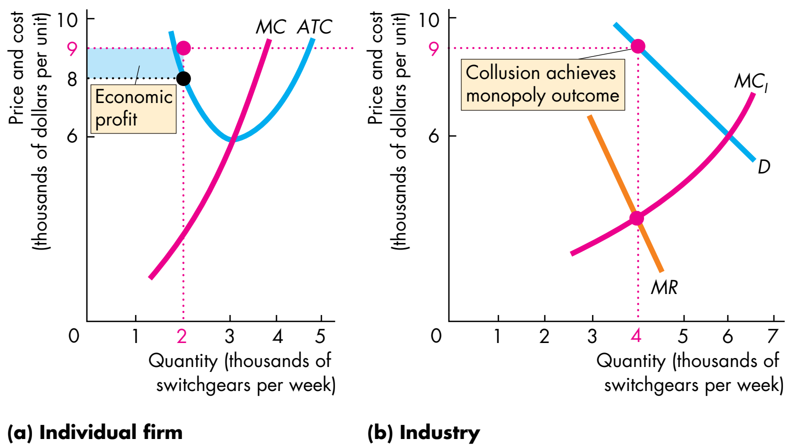
To hold the price at $9,000 a unit, production must be 4,000 units a week. So Trick and Gear must agree on output rates for each of them that total 4,000 units a week. Let's suppose that they agree to split the market equally so that each firm produces 2,000 switchgears a week. Because the firms are identical, this division is the most likely.

The average total cost (*ATC*) of producing 2,000 switchgears a week is $8,000, so the profit per unit is $1,000 and economic profit is $2 million (2,000 units × $1,000 per unit). The economic profit of each firm is represented by the blue rectangle in Fig. 15.3(a).

We have just described one possible outcome for a duopoly game: The two firms collude to produce the monopoly profit-maximizing output and divide that output equally between themselves. From the industry point of view, this solution is identical to a monopoly. A duopoly that operates in this way is indistinguishable from a monopoly. The economic profit that is made by a monopoly is the maximum total profit that can be made by the duopoly when the firms collude.

But with price greater than marginal cost, either firm might think of trying to increase profit by cheating on the agreement and producing more than the agreed amount. Let's see what happens if one of the firms does cheat in this way.

FIGURE 15.3 Colluding to Make Monopoly Profits



The industry marginal cost curve, MC_I in part (b), is the horizontal sum of the two firms' marginal cost curves, *MC* in part (a). The industry marginal revenue curve is *MR*. To maximize profit, the firms produce 4,000 units a week (the quantity at which marginal revenue equals marginal cost). They sell that output for $9,000 a unit. Each firm produces 2,000 units a week. Average total cost is $8,000 a unit, so each firm makes an economic profit of $2 million (blue rectangle)—2,000 units multiplied by $1,000 profit a unit.

One Firm Cheats on a Collusive Agreement To set the stage for cheating on their agreement, Trick convinces Gear that demand has decreased and that it cannot sell 2,000 units a week. Trick tells Gear that it plans to cut its price so that it can sell the agreed 2,000 units each week. Because the two firms produce an identical product, Gear matches Trick's price cut but still produces only 2,000 units a week.

In fact, there has been no decrease in demand. Trick plans to increase output, which it knows will lower the price, and Trick wants to ensure that Gear's output remains at the agreed level.

Figure 15.4 illustrates the consequences of Trick's cheating. Part (a) shows Gear (the complier); part (b) shows Trick (the cheat); and part (c) shows the industry as a whole. Suppose that Trick increases output to 3,000 units a week. If Gear sticks to the agreement to produce only 2,000 units a week, total output is now 5,000 a week, and given demand in part (c), the price falls to $7,500 a unit.

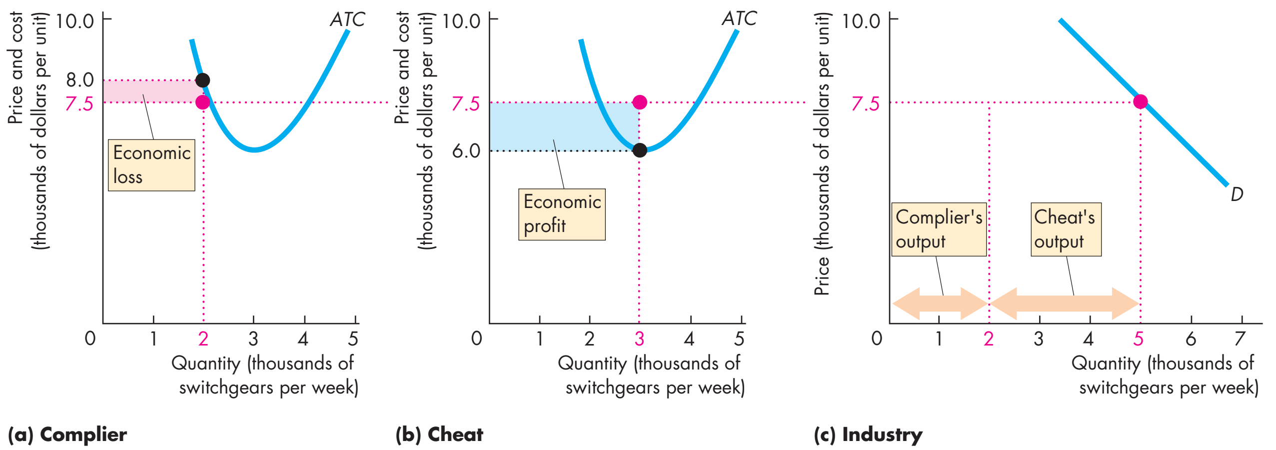
Gear continues to produce 2,000 units a week at a cost of $8,000 a unit and incurs a loss of $500 a unit, or $1 million a week. This economic loss is shown by the red rectangle in part (a). Trick produces 3,000 units a week at a cost of $6,000 a unit. With a price of $7,500, Trick makes a profit of $1,500 a unit and therefore an economic profit of $4.5 million. This economic profit is the blue rectangle in part (b).

We've now described a second possible outcome for the duopoly game: One of the firms cheats on the collusive agreement. In this case, the industry output is larger than the monopoly output and the industry price is lower than the monopoly price. The total economic profit made by the industry is also smaller than the monopoly's economic profit. Trick (the cheat) makes an economic profit of $4.5 million, and Gear (the complier) incurs an economic loss of $1 million. The industry makes an economic profit of $3.5 million. This industry profit is $0.5 million less than the economic profit that a monopoly would make, but it is distributed unevenly. Trick makes a bigger economic profit than it would under the collusive agreement, while Gear incurs an economic loss.

A similar outcome would arise if Gear cheated and Trick complied with the agreement. The industry profit and price would be the same, but in this case, Gear (the cheat) would make an economic profit of $4.5 million and Trick (the complier) would incur an economic loss of $1 million.

Let's next see what happens if both firms cheat.

FIGURE 15.4 One Firm Cheats



One firm, shown in part (a), complies with the agreement and produces 2,000 units. The other firm, shown in part (b), cheats on the agreement and increases its output to 3,000 units a week. Given the market demand curve, shown in part (c), and with a total production of 5,000 units a week, the price falls to $7,500 a unit. At this price, the complier in part (a) incurs an economic loss of $1 million ($500 per unit × 2,000 units), shown by the red rectangle. In part (b), the cheat makes an economic profit of $4.5 million ($1,500 per unit × 3,000 units), shown by the blue rectangle.

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Both Firms Cheat Suppose that both firms cheat and that each firm behaves like the cheating firm that we have just analyzed. Each tells the other that it is unable to sell its output at the going price and that it plans to cut its price. But because both firms cheat, each will propose a successively lower price. As long as price exceeds marginal cost, each firm has an incentive to increase its production—to cheat. Only when price equals marginal cost is there no further incentive to cheat. This situation arises when the price has reached $6,000. At this price, marginal cost equals price. Also, price equals minimum average total cost. At a price less than $6,000, each firm incurs an economic loss. At a price of $6,000, each firm covers all its costs and makes zero economic profit. Also, at a price of $6,000, each firm wants to produce 3,000 units a week, so the industry output is 6,000 units a week. Given the demand conditions, 6,000 units can be sold at a price of $6,000 each.

Figure 15.5 illustrates the situation just described. Each firm, in part (a), produces 3,000 units a week, and its average total cost is a minimum ($6,000 per unit). The market as a whole, in part (b), operates at the point at which the market demand curve (*D*) intersects the industry marginal cost curve (MC_I). Each firm has lowered its price and increased its output to try to gain an advantage over the other firm. Each has pushed this process as far as it can without incurring an economic loss.

We have now described a third possible outcome of this duopoly game: Both firms cheat. If both firms cheat on the collusive agreement, the output of each firm is 3,000 units a week and the price is $6,000 a unit. Each firm makes zero economic profit.

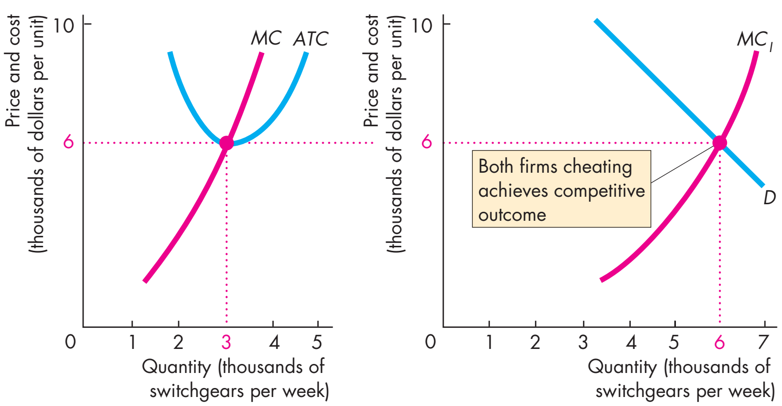
The Payoff Matrix Now that we have described the strategies and payoffs in the duopoly game, we can summarize the strategies and the payoffs in the form of the game's payoff matrix. Then we can find the Nash equilibrium.

Table 15.2 sets out the payoff matrix for this game. It is constructed in the same way as the payoff matrix for the prisoners' dilemma in Table 15.1. The squares show the payoffs for the two firms—Gear and Trick. In this case, the payoffs are profits. (For the prisoners' dilemma, the payoffs were losses.)

The table shows that if both firms cheat (top left), they achieve the perfectly competitive outcome—each firm makes zero economic profit. If both firms comply (bottom right), the industry makes the monopoly profit and each firm makes an economic profit of $2 million. The top right and bottom left squares show the payoff if one firm cheats while the other complies. The firm that cheats makes an economic profit of $4.5 million, and the one that complies incurs a loss of $1 million.

Nash Equilibrium in the Duopolists' Dilemma The duopolists have a dilemma like the prisoners' dilemma. Do they comply or cheat? To answer this question, we must find the Nash equilibrium.

FIGURE 15.5 Both Firms Cheat



(a) Individual firm **(b) Industry**

If both firms cheat by increasing production, the collusive agreement collapses. The limit to the collapse is the competitive equilibrium. Neither firm will cut its price below $6,000 (minimum average total cost) because to do so will result in losses. In part (a), each firm produces 3,000 units a week at an average total cost of $6,000. In part (b), with a total production of 6,000 units, the price falls to $6,000. Each firm now makes zero economic profit. This output and price are the ones that would prevail in a competitive industry.

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TABLE 15.2 Duopoly Payoff Matrix

		Gear's strategies	
		Cheat	Comply
Trick's strategies	Cheat	$0 $0	−$1.0m +$4.5m
	Comply	+$4.5m −$1.0m	+$2m +$2m

Each square shows the payoffs from a pair of actions. For example, if both firms comply with the collusive agreement, the payoffs are recorded in the bottom right square. The red triangle shows Gear's payoff, and the blue triangle shows Trick's. In Nash equilibrium, both firms cheat.

Look at things from Gear's point of view. Gear reasons as follows: Suppose that Trick cheats. If I comply, I will incur an economic loss of $1 million. If I also cheat, I will make zero economic profit. Zero is better than *minus* $1 million, so I'm better off if I cheat. Now suppose Trick complies. If I cheat, I will make an economic profit of $4.5 million, and if I comply, I will make an economic profit of $2 million. A $4.5 million profit is better than a $2 million profit, so I'm better off if I cheat. So regardless of whether Trick cheats or complies, it pays Gear to cheat. Cheating is Gear's best strategy.

Trick comes to the same conclusion as Gear because the two firms face an identical situation. So both firms cheat. The Nash equilibrium of the duopoly game is that both firms cheat. And although the industry has only two firms, they charge the same price and produce the same quantity as those in a competitive industry. Also, as in perfect competition, each firm makes zero economic profit.

This conclusion is not general and will not always arise. We'll see why not by looking first at some other games that are like the prisoners' dilemma. Then we'll broaden the types of games we consider.

Other Oligopoly Games

Firms in oligopoly must decide whether to mount expensive advertising campaigns; whether to modify their product; whether to make their product more reliable and more durable; whether to price discriminate and, if so, among which groups of customers and to what degree; whether to undertake a large research and development (R&D) effort aimed at lowering production costs; and whether to enter or leave an industry.

All of these choices can be analyzed as games that are similar to the one that we've just studied. Let's look at one example: an R&D game.

Economics in Action

An R&D Game in the Market for Diapers

Disposable diapers have been around for a bit more than 40 years. Procter & Gamble (which has a 40 percent market share with Pampers) and Kimberly-Clark (which has a 33 percent market share with Huggies) have always been the market leaders.

When the disposable diaper was first introduced, it had to be cost-effective in competition with reusable, laundered diapers. A costly research and development effort resulted in the development of machines that could make disposable diapers at a low enough cost to achieve that initial competitive edge. But new firms tried to get into the business and take market share away from the two industry leaders, and the industry leaders themselves battled each other to maintain or increase their own market shares.

During the early 1990s, Kimberly-Clark was the first to introduce Velcro closures. And in 1996, Procter & Gamble was the first to introduce "breathable" diapers.

The key to success in this industry (as in any other) is to design a product that people value highly relative to the cost of producing it. The firm that creates the most highly valued product and also develops the least-cost technology for producing it gains a competitive edge, undercutting the rest of the market, increasing its market share, and increasing its profit.

But the R&D that must be undertaken to improve product quality and cut cost is itself costly. So the cost of R&D must be deducted from the profit resulting from the increased market share that lower costs achieve. If no firm does R&D, every firm can be better off, but if one firm initiates the R&D activity, all must follow.

Table 15.3 illustrates the dilemma (with hypothetical numbers) for the R&D game that Kimberly-Clark and Procter & Gamble play. Each firm has two strategies: Spend $25 million a year on R&D or spend nothing on R&D. If neither firm spends on R&D, they make a joint profit of $100 million: $30 million for Kimberly-Clark and $70 million for Procter & Gamble (bottom right of the payoff matrix). If each firm conducts R&D, market shares are maintained but each firm's profit is lower by the amount spent on R&D (top left square of the payoff matrix). If Kimberly-Clark pays for R&D but Procter & Gamble does not, Kimberly-Clark gains a large part of Procter & Gamble's market. Kimberly-Clark profits, and Procter & Gamble loses (top right square of the payoff matrix). Finally, if Procter & Gamble conducts R&D and Kimberly-Clark does not, Procter & Gamble gains market share from Kimberly-Clark, increasing its profit, while Kimberly-Clark incurs a loss (bottom left square).

TABLE 15.3 Pampers Versus Huggies: An R&D Game

Kimberly-Clark's strategies	Procter & Gamble's strategies: R&D	Procter & Gamble's strategies: No R&D
R&D	$45m $5m	−$10m +$85m
No R&D	+$85m −$10m	+$70m +$30m

If both firms undertake R&D, their payoffs are those shown in the top left square. If neither firm undertakes R&D, their payoffs are in the bottom right square. When one firm undertakes R&D and the other one does not, their payoffs are in the top right and bottom left squares. The red triangle shows Procter & Gamble's payoff, and the blue triangle shows Kimberly-Clark's. The Nash equilibrium for this game is for both firms to undertake R&D. The structure of this game is the same as that of the prisoners' dilemma.

Confronted with the payoff matrix in Table 15.3, the two firms calculate their best strategies. Kimberly-Clark reasons as follows: If Procter & Gamble does not undertake R&D, we will make $85 million if we do and $30 million if we do not; so it pays us to conduct R&D. If Procter & Gamble conducts R&D, we will lose $10 million if we don't and make $5 million if we do. Again, R&D pays off. So conducting R&D is the best strategy for Kimberly-Clark. It pays, regardless of Procter & Gamble's decision.

Procter & Gamble reasons similarly: If Kimberly-Clark does not undertake R&D, we will make $70 million if we follow suit and $85 million if we conduct R&D. It therefore pays to conduct R&D. If Kimberly-Clark does undertake R&D, we will make $45 million by doing the same and lose $10 million by not doing R&D. Again, it pays us to conduct R&D. So for Procter & Gamble, R&D is also the best strategy.

Because R&D is the best strategy for both players, it is the Nash equilibrium. The outcome of this game is that both firms conduct R&D. They make less profit than they would if they could collude to achieve the cooperative outcome of no R&D.

The real-world situation has more players than Kimberly-Clark and Procter & Gamble. A large number of other firms share a small portion of the market, all of them ready to eat into the market share of Procter & Gamble and Kimberly-Clark. So the R&D efforts by these two firms not only serve the purpose of maintaining shares in their own battle but also help to keep barriers to entry high enough to preserve their joint market share.

The Disappearing Invisible Hand

All the games that we've studied are versions of the prisoners' dilemma. The essence of that game lies in the structure of its payoffs. The worst possible outcome for each player arises from cooperating when the other player cheats. The best possible outcome, for each player to cooperate, is not a Nash equilibrium because it is in neither player's *self-interest* to cooperate if the other one cooperates. It is this failure to achieve the best outcome for both players—the best social outcome if the two players are the entire economy—that led John Nash to claim (as he was portrayed as doing in the movie *A Beautiful Mind*) that he had challenged Adam Smith's idea that we are always guided, as if by an invisible hand, to promote the social interest when we are pursuing our self-interest.

A Game of Chicken

The Nash equilibrium for the prisoners' dilemma is unique: both players cheat (confess). Not all games have a unique equilibrium, and one that doesn't is a game called "chicken."

An Example of the Game of Chicken A graphic, if disturbing, version of "chicken" has two cars racing toward each other. The first driver to swerve and avoid a crash is the "chicken." The payoffs are a big loss for both if no one "chickens out;" zero for both if both "chicken out;" and zero for the chicken and a gain for the one who stays the course. If player 1 swerves, player 2's best strategy is to stay the course; and if player 1 stays the course, player 2's best strategy is to swerve.

An Economic Example of Chicken An economic game of chicken can arise when R&D creates a new technology that cannot be kept secret or patented, so both firms benefit from the R&D of either firm. The chicken in this case is the firm that does the R&D.

Suppose, for example, that either Apple or Nokia spends $9 million developing a new touch-screen technology that both would end up being able to use regardless of which of them developed it.

Table 15.4 illustrates a payoff matrix for the game that Apple and Nokia play. Each firm has two strategies: Do the R&D ("chicken out") or do not do the R&D. Each entry shows the additional profit (the profit from the new technology minus the cost of the research), given the strategies adopted.

If neither firm does the R&D, each makes zero additional profit. If both firms conduct the R&D, each firm makes an additional $5 million. If one of the firms does the R&D ("chickens out"), the chicken makes $1 million and the other firm makes $10 million. Confronted with these payoffs the two firms calculate their best strategies. Nokia is better off doing R&D if Apple does no R&D. Apple is better off doing R&D if Nokia does no R&D. There are two Nash equilibrium outcomes: Only one of them does the R&D, but we can't predict which one.

You can see that an outcome with no firm doing R&D isn't a Nash equilibrium because one firm would be better off doing it. Also both firms doing R&D isn't a Nash equilibrium because one firm would be better off *not* doing it. To decide *which* firm does the R&D, the firms might toss a coin, called a mixed strategy.

TABLE 15.4 An R&D Game of Chicken

Nokia's strategies	Apple's strategies: R&D	Apple's strategies: No R&D
R&D	Apple $5m; Nokia $5m	Apple $10m; Nokia $1m
No R&D	Apple $1m; Nokia $10m	Apple $0; Nokia $0

If neither firm does the R&D, their payoffs are in the bottom right square. When one firm "chickens out" and does the R&D while the other does no R&D, their payoffs are in the top right and bottom left squares. When both "chicken out" and do the R&D, the payoffs are in the top left square. The red triangle shows Apple's payoff, and the blue triangle shows Nokia's. The equilibrium for this R&D game of chicken is for only one firm to undertake the R&D. We cannot tell which firm will do the R&D and which will not.

REVIEW QUIZ

1. What are the common features of all games?
2. Describe the prisoners' dilemma game and explain why the Nash equilibrium delivers a bad outcome for both players.
3. Why does a collusive agreement to restrict output and raise price create a game like the prisoners' dilemma?
4. What creates an incentive for firms in a collusive agreement to cheat and increase production?
5. What is the equilibrium strategy for each firm in a duopolists' dilemma and why do the firms not succeed in colluding to raise the price and profits?
6. Describe two structures of payoffs for an R&D game and contrast the prisoners' dilemma and the chicken game.

You can work these questions in Study Plan 15.2 and get instant feedback.